MASTER OF SCIENCE
IN
PHYSICAL OCEANOGRAPHY

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STUDIES OF SOUTH CHINA SEA CIRCULATION AND THERMAL STRUCTURE USING A THREE DIMENSIONAL NUMERICAL MODEL

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The seasonal ocean circulation and thermal structure in the South China Sea (SCS) were studied numerically using the Princeton Ocean Model (POM) with 20 km horizontal resolution and 23 sigma levels conforming to a realistic bottom topography. A sixteen month control run was performed using climatological monthly mean wind stresses and restoring type salt and heat fluxes as surface forcing terms and observational oceanic inflow/outflow at the open boundaries. The seasonally averaged effects of isolated forcing terms are presented and analyzed from the following experiments: l) non-linear effects removed, 2) wind effects removed, 3) open boundary inflow/outflow set to zero, and 4) open boundary inflow/outflow doubled. This procedure allowed analysis of the contribution of the isolated parameter to the general hydrology of the SCS and some of its specific features. A coastal jet is identified and analyzed, as are a mesoscale topographic gyre and several counter currents. Non-linearity is shown to be important to the energy and volume transport of baroclinic eddy features, but otherwise insignificant. Boundary transport from open lateral boundaries is determined to be of considerable importance to summer circulation and thermal structure, with little effect found for the winter monsoon hydrology. In general, monsoonal circulation patterns and upwelling phenomena are determined and forced by the wind, while boundary transport effects play a secondary role in determining the magnitude of circulation velocities.

INFRAGRAVITY WAVES ON THE CONTINENTAL SHELF

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The variability of infragravity-frequency (0.004-0.04 Hz) motions on a wide continental shelf was examined with data from a l00km-long transect of bottom pressure recorders extending from the beach (6m depth) to the shelf break (87m depth) near Duck, North Carolina. The observed infragravity motions are a mixture of forced waves, phase-coupled to local wave groups, and (uncoupled) free waves. Although the contribution of forced waves to the infragravity energy increases with both increasing swell energy and decreasing water depth, the shelf is usually dominated by free waves. The observed tree waves are predominantly radiated from nearby beaches. The strong attenuation of infragravity waves observed across the inner shelf is primarily the result of refractive trapping and is well described by a WKB model. Across the flatter, irregular outer shelf the observed attenuation is weaker but increases with increasing swell energy, suggesting that significant damping occurs on the shelf during storms, consistent with earlier studies. At the deepest instrumented sites, weaker correlations between infragravity and swell energy levels, and weaker depth dependence of infragravity energy levels are observed, suggesting that remotely generated waves are important seaward of the shelf break.

SWELL PROPAGATION ACROSS A WIDE CONTINENTAL SHELF

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The effects of wave refraction and damping on swell propagation across a wide continental shelf were examined with data from a transect of bottom pressure recorders extending from the beach to the shelf break near Duck, North Carolina. The observations generally show weak variations in swell energy across the shelf during benign conditions, in qualitative agreement with predictions of a spectral refraction model. Although the predicted ray trajectories are quite sensitive to the irregular shelf bathymetry, the predicted energy variations are surprisingly weak, consistent with the observations. The results indicate that small amplitude swell is not significantly damped on the shelf. However, a large decrease in swell energy levels across the shelf (up to 70%), observed with high-energy incident swell, is not predicted by the energy conserving refraction model. These energy losses are likely caused by bottom friction.

THE EFFECT OF SALINITY ON DENSITY IN THE LEEUWIN CURRENT SYSTEM

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Climatological temperature and salinity fields are used to calculate the salinity contribution to density and dynamic height fields in the Leeuwin Current System (LCS). While the temperature gradient is primarily linear, with warmest water to the north, the salinity fields are spatially inhomogenous. A comparison of density fields, calculated with constant and variable salinity, shows that, off Western Australia the density field is primarily determined by temperature. Off Southern Australia, the density field is dependent on warm and salty (subtropical) and fresh and cold (sub-Antarctic) water masses. While the dynamic height fields, calculated with constant and variable salinity, show similar flow patterns off Western Australia, different flow patterns are found off Southern Australia.

In addition to the analysis of climatological fields, a primitive equation ocean model is used to investigate the role of salinity in the formation of currents and eddies in the LCS. Two identical ocean models, one with a climatological salinity field and the other with no horizontal salinity gradients, are run and compared with each other. Despite the model runs being initialized with similar temperature distributions, there are relatively large temperature and density differences in the Southern Australian region, due to the advection of water masses by the Leeuwin Current.

Based on the climatological analyses and the results of the model experiments, it is concluded that, descriptively and dynamically, both temperature and salinity are essential to accurately characterize the large-scale circulation of the LCS.

WAVE SLOPES AND BREAKING DISTRIBUTIONS IN THE SURF ZONE

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Field measurements from a cross-shore array of nine pressure sensors, spanning the surf zone, are used to examine the evolution of ensemble averaged wave face slopes of ocean waves as they propagate through the breaking region. Averaged wave slopes are determined from time series of the measured sea surface elevation and from an averaged waveform calculated from bispectral coefficients, and compared with predictions from a wave transformation model

that includes wave breaking described by rollers. Measured percent wave breaking are used to examine the evolution of third moment and bispectral statistics in relation to breaking patterns.

Shoaling waves gradually transform from peaked, Stokes-like waves to forward pitched asymmetric waves just prior to breaking. Inside the surf zone, wave asymmetry is modified by the breaking distributions and the effects of bottom topography. The observations suggest a relationship between the cross-shore wave breaking distributions and wave slopes. Wave slopes predicted using a calibrated wave transformation model which includes wave rollers are in qualitative agreement with measured wave slopes.

The results showed that strong ESL (5 to 10 dB) existed over a sand (reflective) bottom and was generally invariant with range. ESL was correlated with TL, i.e., areas of high spreading loss were found in regions of high TL. ESL was not as large (3 to 5 dB) over silt/clay (absorptive) bottoms due to the increased absorption of the bottom refracted path thus reducing the number of multipath modes. Broadband pulses were found to exhibit fewer fluctuation than single frequency signals, and generally the total TL loss was a few dB larger than a single cw case. To overcome the ESL, integration techniques based on an accurate prediction model in the post analyzing system are required with a high temporal resolution of the echo energy shape.

THE JAN MAYEN CURRENT FROM 1989 AND 1990 SUMMER DATA

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As part of the Greenland Sea Project, a hydrographic survey consisting of 45 CTD stations was conducted in the vicinity of the Jan Mayen Current (JMC) in August 1990 aboard the USNS BARTLETT to further characterize and quantify circulation of the JMC. Comparisons were made with a similar survey performed in September 1989. In the summer of l990, as in 1989, the JMC appears to be both a portion of the East Greenland Current (EGC) flowing eastward to close the Greenland Sea Gyre (GSG) and anticyclonic meander in the EGC flow north of Jan Mayen. Geostrophic velocities and transports were similar for 1990 and 1989 with typical near-surface speeds of 3 cm/s slowing to 1 cm/s at depth. The total input flow to the JMC from the EGC is estimated at 1.45 Sv for August 1990 compared to 2 Sv during September 1989. Baroclinic calculations for 1990 data indicate that the meander portion of the JMC is concentrated in the upper waters (~ 100 m) with the result that 44% of the upper layer and 25% of the lower layer (~ 100 1000 m) flow contributes to the JMC meander. The remainder, ~ 56% from the surface and 75% from the lower layer, continues eastward as throughput to the GSG. Similarly, in 1989, it was determined that about half of the upper layer flow is involved in the meander with flow becoming more easterly at depth. In l990, the surface was warmer and fresher, the subsurface temperature minimum was colder, and the volume of water occupied by JMC type water masses was half the amount when compared to 1989 data.

SMALL-SCALE MORPHOLOGY RELATED TO WAVE AND CURRENT PARAMETERS ACROSS THE SURF ZONE

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Small-scale beach morphology (scales < 5 m) height variations were measured by combining the CRAB survey with bed elevation acquired from a 1 MHz sonic altimeter mounted on the CRAB during the October Phase of the DUCK94 experiment. Bedform types were observed using a 500 kHz side-scan sonar also mounted on the CRAB. Corollary waves and currents were measured. Three cases were examined in detail: mild waves and weak longshore currents resulting in wave ripples everywhere; storm waves with strong longshore currents resulting in lunate and straight

crested megaripples in the trough of the barred beach; and narrow banded, normally incident waves with a strong rip current resulting in a relatively planar bed everywhere except in the throat of the rip where megaripples were measured. The predictive wave ripple height and length equations of Nielsen (1981) worked reasonably well for mild wave conditions, but did not predict ripples during moderate wave conditions. The wavenumber spectra were generally broad, indicating that newly formed ripples coexisted with residual ripples from the past to form complex, multi-scaled ripple patterns.

AN ANALYSIS OF ENERGY SPREADING LOSS ASSOCIATED WITH TACTICAL ACTIVE SONAR PERFORMANCE IN A SHALLOW WATER ENVIRONMENT

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Energy spreading loss (ESL) is qualitatively defined as the reduction in peak echo level due to energy spreading of the transmitted acoustic pulse in time. An analysis of the impact of shallow water propagation on ESL was performed with the aid of a high performance computer using the FEPE_SYN and EXT_TD programs to compute the spreading of the received pulse due to multipath propagation in shallow water. A Blackman windowed pulse was used to model the transmitted pulse, which was centered at 3.5 kHz, with 200 Hz bandwidth. For input parameters, typical seasonal sound speed profiles and a Hamilton geoacoustic model of Area Foxtrot off the U.S. eastern seaboard was used. ESL's impact on sonar performance was determined as a function of range, source and target depth, sound speed profiles and geoacoustic properties. The impact of shallow water propagation on the correlation of the transmitted and propagated pulses through the quantitative definition of mismatch loss (MML) was also discussed.

The results showed that strong ESL (5 to 10 dB) existed over a sand (reflective) bottom and was generally invariant with range. ESL was correlated with TL, i.e., areas of high spreading loss were found in regions of high TL. ESL was not as large (3 to 5 dB) over silt/clay (absorptive) bottoms due to the increased absorption of the bottom refracted path thus reducing the number of multipath modes. Broadband pulses were found to exhibit fewer fluctuation than single frequency signals, and generally the total TL loss was a few dB larger than a single cw case. To overcome the ESL, integration techniques based on an accurate prediction model in the post analyzing system are required with a high temporal resolution of the echo energy shape.